CHAPTER 2

SIGNIFICANCE OF SOIL ORGANIC MATTER IN RELATION TO PLANTS AND THEIR PRODUCTS

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2.1 SOIL ORGANIC MATTER

Soil organic matter (OM) has been used as plant growth promoter and regulator since the advent of human civilization. Considering the history of plant sciences, much prior to the auxin concept establishment, the term "auximones" was coined to describe plant growth-promoting humic acids extracted from peat (Zandonadi et al., 2013). The biggest and original source of soil OM is plant tissue. Under natural conditions, the tops and roots of trees, shrubs and grasses, and other native plants annually supply large quantities of organic residues. Soil organisms decompose all these organic materials which eventually become part of the underlying soil by infiltration or physical incorporation (Lee et al., 2014). Comparatively, animals, however, are considered secondary sources of OM after plants. The animal feces or the waste products are incorporated into the soil system after decay and detritivory. Certain forms of animal life, especially the earthworms, termites, ants, and others, also play an important role in the translocation of soil and plant residues within the soil system (Filley et al., 2008; Dowuona et al., 2012). Figure 2.1 portrays a schematic representation of soil OM. In addition to other soil factors, the OM content of a soil is intimately related to its productivity. Soil OM is an important feature of the soil system which varies significantly with soil type, climatic conditions, and land-use pattern (Craswell & Lefroy, 2001). The soil OM supports the soil system in various ways. Some of the functional significances of soil OM are as follows (Brady, 1995):

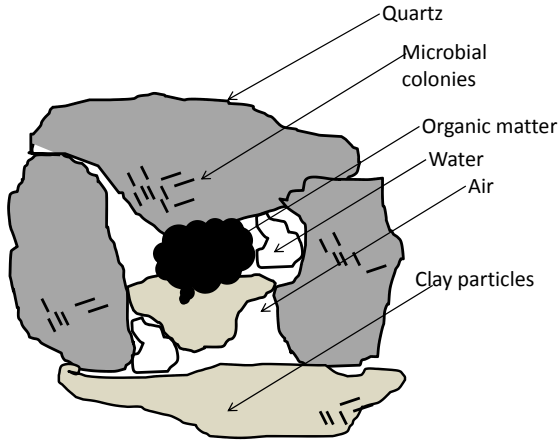


FIGURE 2.1 Schematic representation of soil organic matter complex.

- OM acts as a storehouse of plant nutrients (N, P, S, etc.);
- OM increases exchange capacity of cations and anions;
- OM provides energy for microbial activity;
- OM increases water-holding capacity of soil;
- OM improves soil structure;
- OM reduces crusting and increases infiltration;
- OM reduces the effects of compaction; and
- OM buffers the soil against rapid changes in acidity, alkalinity, and salinity.

The above stated factors coordinately impart "tilth" to the soil. The production of large quantities of residues, and their subsequent decay, is necessary for good soil tilth and productivity.

2.2 DECOMPOSITION OF OM

The decomposition or disintegration of OM is a long-time process. Various biotic and abiotic factors influence the process of OM decomposition. Climatic factors like temperature and moisture play an important role in the decomposition process (Conant et al., 2011; Gabriel & Kellman, 2014). Soil clay content supports a faster rate of OM decomposition in soil (Wei et al., 2014). Apart from the stated factors, many soil organisms also modify the soil system by full or partial decomposition of OM (Xu et al., 2015). This is due to the complex architecture of the various components of OM. The general composition of soil OM involves carbohydrates (starch, cellulose, hemi-cellulose, etc.), lignin (found in woody plant tissue), fats and oils (found primarily in seeds), crude protein, crude fiber, and others. Organic compounds vary greatly in their rate of decomposition. They may be listed in terms of ease of decomposition as follows (Brady, 1995):

- Sugars, starches, and simple proteins — rapid decomposition
- Crude proteins
- Hemicelluloses
- Cellulose
- Fats, waxes, etc.
- Lignins — very slow decomposition

The initiation of decomposition process of organic materials is triggered with the addition of fresh plant tissue to soil. The sugars and simple proteins decompose most readily; at the other extreme; lignins are the most resistant to breakdown. When organic tissue is added to soil, three general reactions take place (Brady, 1995):

- The biggest proportion of material faces enzymatic oxidation with the liberation of CO_2, H_2O, energy, and heat.
- Mineralization or immobilization of macro or microelements occurs through element-specific reactions.
- Reconstitution of complex organic compounds takes place with the involvement of plant and microbial entities and these compounds collectively comprise soil humus.

Decomposition of OM is an oxidation process when all the organic compounds found in residues are disintegrated with evolution of energy. The oxidation reaction can be summed as follows.

$$\underset{\text{C, H-containing compounds}}{-(C,4H)} + 2O_2 \xrightarrow{\text{enzymatic oxidation}} CO_2 + 2H_2O + \text{Energy}$$

Many intermediate steps are involved in this overall reaction, and it is accompanied by important side reactions that involve elements other than C and H. This basic reaction answers the complex decomposition pathway of OM in the soil as well as the oxygen consumption and release of CO_2. For example, during protein decay amino acids like glycine and cysteine are produced apart from CO_2 and H_2O. In turn, these amino acids are further broken down by microbial action, eventually yielding simple inorganic ions like NH_4^+, NO_3^-, and SO_4^{2-} (Wheeler, 1963).

2.3 CARBON CYCLE

As OM decays, CO_2 is among the immediate breakdown products. C is a common constituent of all OM and is involved in essentially all life processes. Thus, the transformation of this element is also termed as "biocycle" that makes possible the continuity of life on earth (Fig. 2.2). The soil OM influences various soil processes like evolution and consumption of greenhouse gases (CH_4, N_2O, etc.) (Horwath, 2015). Carbon cycling in

soil is under strict microbial operation (Schimel & Schaeffer, 2012). There are several components in the C-cycle machinery termed as pool, stock or reservoir, and flux. The pool is the store house for large amount of C operating in the earth system. Soil is a large pool for C sequestration, holding about 75% of the C operating in the atmosphere. The tropical forests represent one-third of the total metabolic activity on the land surface (Malhi, 2012). Any movement of C between the reservoirs is called flux. In any integrated system, fluxes connect reservoirs together to create cycles and feedbacks.

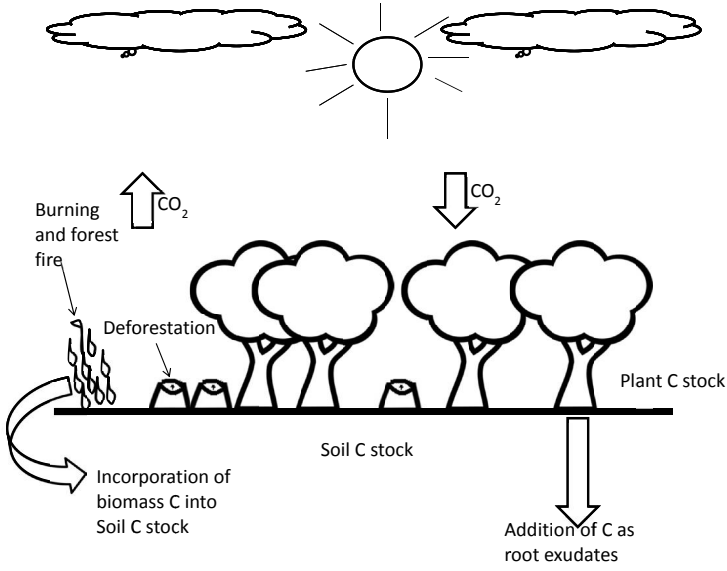


FIGURE 2.2 An illustration of carbon cycle in forest ecosystem.

2.3.1 RELEASE OF CO_2

Through the process of photosynthesis, CO_2 is stored and incorporated by higher plants and resynthesized into numerous organic compounds (Simpraga et al., 2011). When these organic compounds reach the soil with plant residues, they undergo digestion, and CO_2 is liberated. Microbial activity is the main soil source of CO_2, although appreciable amounts come from respiration of plant roots, and small amounts are brought down dissolved in rain water (Rastogi et al., 2002). Much of the CO_2 of the soil

ultimately escapes to the atmosphere, where it can again be used by plants, thus completing the cycle. A meager amount of CO_2 reacts in the soil that produces carbonic acid, carbonates, and bicarbonates of Ca, K, Mg, and other base-forming cations. The bicarbonates are readily soluble and can be removed in drainage or used by higher plants (Tyler & Olsson, 2001).

2.3.2 OTHER CARBON PRODUCTS OF DECAY

The decay of OM forms a series of carbon products. Small quantities of elemental C are found in soil (Nicolas et al., 2012). Under highly anaerobic conditions, CH_4 and CS_2 may be produced in small amounts. But of all the simple C products, CO_2 is by far the most abundant. The C-cycle is all inclusive because it involves soil and its flora and fauna.

2.4 SOIL HUMUS

Humus is a complex and rather resistant mixture of brown amorphous and colloidal organic substances that results from microbial decomposition and synthesis and has chemical and physical properties of great significance to soils and plants (Brady, 1995). There are different kinds of humus forms found in the soils around the globe. The most popular forms of humus are mull, moder, and mor (Ponge, 2013). Mixing of the soil OM, minerals, plant exudation, animals, and microbial excreta lead to the formation of a special type of humus in the upper crumby soil layer called "mull." Again, when soil OM only consists of fungal mycelia and animal excreta and lies over the mineral layer of soil, it is referred to as "moder." When transformation of plant litter occurs slowly leading to its accumulation in the "E" horizon (purely mineral horizon) or in the parent rock, it is called "mor" (Fig. 2.3). Some other forms of humus are "amphi" and "tangel" which are mainly described on calcareous parent rocks in Mediterranean and subalpine climatic conditions (Galvan et al., 2008).

The complex compounds that make up humus are not merely degraded plant materials but mostly the bulk of these compounds have resulted from two general types of biochemical reactions: decomposition and synthesis. Decomposition starts as chemicals in the plant residues which are further subjected to disintegration by soil organisms. Even lignin is degraded by the intense microbial reactions. The second humus-forming step is termed

as biochemical synthesis when the simpler organic compounds coming from the breakdown of the parent organic complexes get involved. These simpler chemicals are metabolized into new compounds in the body tissue of the soil microorganisms (Matsumura, 1987). The new compounds are subject to further modification and synthesis as the microbial tissue is subsequently attacked by other soil microorganisms. Some other additional synthetic reactions involve such breakdown products of lignin as the phenols and quinines (Camarero et al., 1994). These decomposition products, present initially as separate molecules called monomers, are enzymatically stimulated to join together into polymers. By this process of polymerization, polyphenols and polyquinones are formed (Prusty & Azeez, 2015). These high molecular weight compounds interact with N-containing amino compounds and give rise to a significant component of resistant humus. The formation of these polymers is encouraged by the presence of colloidal clays.

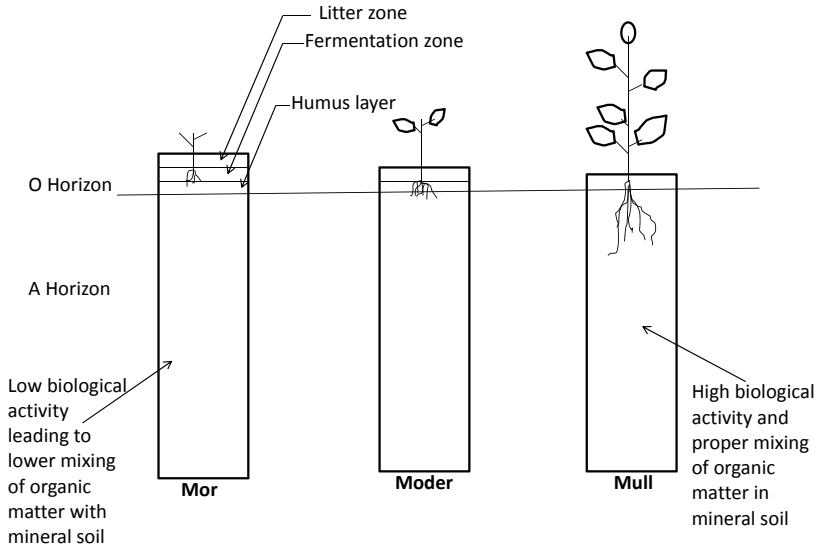


FIGURE 2.3 Schematic diagram of three major types of humus in soil

The humic substances make up to 60–80% of the soil OM (Trevisan et al., 2010). Humic substances are characterized by aromatic structures and include polyphenols and polyquinones, which are even more complex. The humic substances have no sharply defined physical or chemical

properties, which are characteristic of more simple nonhumic compounds (Prusty & Azeez, 2015). They are amorphous, dark in color, and have very high molecular weights. On the basis of resistance to degradation and of solubility in acids and alkalis, humic substances have been classified into three chemical groupings: (a) fulvic acid, (b) humic acid, and (c) humin. Fulvic acid has the lowest molecular weight of the three, is soluble in both acid and alkali, and is most susceptible to microbial attack. Humic acid is medium in molecular weight and color, soluble in alkali, insoluble in acid, and intermediate in resistance to microbial degradation. Humin has the highest molecular weight, darkest in color, insoluble in both acid, and alkali, and most resistant to microbial attack (Brady, 1995). Despite differences in chemical and physical makeup, the three humic groups have some similarities with regard to properties, such as ability to absorb and release cations, and hence they are collectively called humic substances.

Apart from the humic group, the soil OM consists of a considerable proportion of nonhumic substances. The nonhumic are less complex and less resistant to microbial attack compared to humic substances. They are comprised of specific organic compounds with definite physical and chemical properties. Some of these nonhumic materials are only modified by microbial action while others are synthesized as break-down occurrs. The usual nonhumic compounds in soil are polysaccharides, polymers that have sugar-like structures, polyuronides, and so on. Some simpler compounds like organic acids and protein-like materials are also part of nonhumic substances. The humic and the nonhumic components of the OM continually interact with each other. Reactions occur incessantly in the soil system. During the formation of humus, all the intermediate structural compounds continuously react with each other whether humic or nonhumic in nature. For example, proteins and other N-compounds react with a wide variety of organic compounds in both groups, including the humic acids and polysaccharides. These reactions are essential for N-conservation in soils because in the resultant compounds the protein N is somehow protected from microbial attack.

Humic acid is an important soil component that bestows fertility to it and leads to better plant growth and productivity (Dhanpal & Sekar, 2013). Interaction with some layer silicate clays is another way of stabilizing soil N. These clays are known to attract and hold substances such as amino acids, peptides, and proteins, forming complexes that protect the N-containing compounds from microbial decomposition. Specific

protein–clay linkages are not the only important reactions that occur between organic and inorganic compounds in soils. In some cases, clays seem to catalyze some oxidation and polymerization reactions even in the absence of microorganisms (Lee et al., 2004). Also various organomineral complexes involve linkage of phenols or organic acids with silicate clays or iron and aluminum oxides. Humus is subject to continual microbial attack. Without the annual addition of organic residues, microbial action results in a reduction in soil OM levels (Ma et al., 2012). Each time, newly synthesized polymers join those formed in previous time periods. Due to its resistivity toward easy decay, humic compounds are important in maintaining OM levels in soil and also help protect N and other essential elements that are bound in the humic complex.

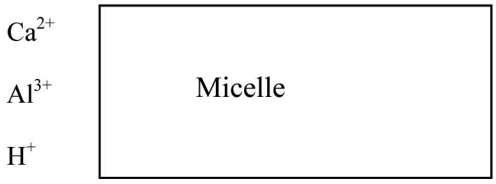
2.4.1 HUMUS–COLLOIDAL CHARACTERISTICS

The humus–colloids are stable soil aggregates which are formed by the mating of mineral nutrients and humic substances. Such complexes are formed by microbial action. Soil pH has an important role in the complexation of humus–colloid (Varadachari et al., 1994). The major characteristics of the humus–colloidal constituents of soil are as follows (Brady, 1995):

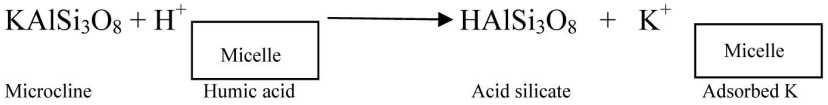
- The tiny colloidal humus particles are composed of C, H, and O mostly in the forms of polyphenols, polyquinones, polyuronides, and polysaccharides.
- The surface area of humus colloids per unit mass is very high, generally exceeding that of silicate clays.
- The colloidal surfaces of humus are negatively charged, the sources of the charge being hydroxyl, carboxylic, or phenolic groups. The extent of the negative charge is pH dependent.
- At high pH, the cation exchange capacity of humus on a mass basis far exceeds that of most silicate clays.
- The water-holding capacity of humus on a mass basis is greater than silicate clays.
- Humus has a very favorable effect on aggregate formation and stability.
- The dark brown color of humus tends to distinguish it from most of the other constituents in soil.

- Cation exchange reactions with humus are qualitatively similar to those occurring with silicate clays.

The humic micelles, like clay particles, carry a swarm of adsorbed cations. Thus, colloidal humus may be represented by the same illustrative formula used for clay.



Humus enhances mineral breakdown and, in turn, nutrient availability in two ways. First, humic acids can attack the minerals and bring about their decomposition, thereby releasing essential base forming cations.



The K is changed from a molecular to an adsorbed state, which is more readily available to higher plants. The second mechanism for increasing the availability of some cations is through the formation of stable organomineral complexes with these ions. For example, polysaccharides and fulvic acids form such complexes with metallic ions such as Fe^{3+}, Cu^{2+}, Zn^{2+}, and Mn^{2+}. The cations are attracted from the minerals in which they are found and held in complex form by the organic molecule. Later, they may be taken up by plants or may take part in the synthesis of clay and other inorganic constituents (Pokrovsky & Schott, 2002).

2.5 INFLUENCE OF ORGANIC COMPOUNDS ON PLANT GROWTH AND METABOLITE PRODUCTION

Important aspects of soil–plant interactions involve the regulating processes that control the accumulation or disintegration of OM coupled with the genesis or disappearance of soil horizons. OM is highly plant

available. For example, certain amino acids like alanine, glycine, and so on, can be directly taken up by the plant roots for usage. The concentration of these amino acids differs highly from soil to soil. In normal conditions, concentration of such amino acids is very meager in amount to meet the plant demand for N. Organic acids like vanillic acids, carboxylic acids, and others, are highly significant for plant use (Brady, 1995). Organic compounds in soil, though present in little amount contain various growth-promoting substances. Humic substances also influence the expression of various plant metabolites. Merlo et al. (1991) reported the positive influence of soil humic substances on the elevated carbohydrate synthesis in maize foliage. A schematic representation of some important plant secondary metabolites is provided in Figure 2.4.

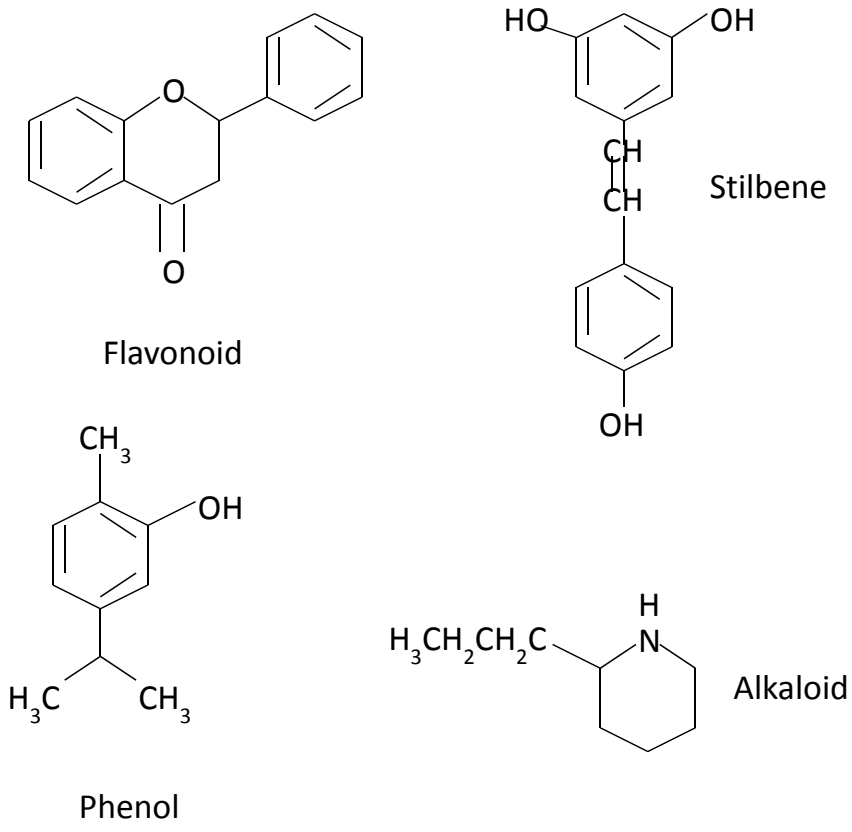


FIGURE 2.4 Schematic representation of some typical plant secondary metabolites.

Organic fertilization imparts high OM in soil which in turn influences the higher production of plant phenols, flavonoids, stilbenes, and so on (Ibrahim et al., 2013). Similar research by Ali et al. (2012) highlights the positive impact of OM on the esculin (bioactive compound) content in *Cichorium intybus* plants. Application of humic substances as foliar spray in tomato enhanced nitrate uptake along with the nitrate reductase activity coupled with the activation of secondary metabolic phenylalanine ammonia lyase pathway (Olivares et al., 2015). Edreva et al. (2008) reported the chemical characteristics and functions of certain plant metabolites (provided in Table 2.1). Application of OM in soil also enhances the flavonolignan (plant metabolite) production in milk thistle (Afshar at al., 2014). Application of agrowaste in the soil system elicits the synthesis of various amino acids and other important metabolites in plant body (Ibrahim & Mumtaz, 2014). Soil humic substances also impart higher plant defense toward pathogens (Berbara & Garcia, 2014). Incorporation of humic substances along with certain bacterial strains results in elevation of ATPase enzyme activity in plants, better N metabolism, and greater net photosynthesis (Canellas et al., 2012). OM decomposition is a time-dependent process. After decomposition, different classes of growth-promoting compounds like vitamins, amino acids, plant hormones (auxins, gibberellins, etc.) are liberated into the soil system. With the surge of such nutritious substances, plant and microbial growth in soil is enhanced manifold. Incorporation of vermistabilized or composted industrial waste products holds much good in boosting plant growth and metabolism. Recent reports show that toxic wastes like paper mill waste, olive mill waste, waste-water sludge, distillery sludge, municipal solid waste, and so on, after vermitreated influence better productivity in plants (Sahariah, et al., 2014; Garcia-Gomez et al., 2002; Vivas et al., 2009; Singh & Suthar, 2012; Ramana et al., 2002). A gist of the influence of various organic inputs on plant metabolite synthesis is provided in Table 2.2.

Plant metabolites like flavonoids, phenols, tannins, stilbenes, alkaloids, and so on, and various enzymes are significantly influenced by the high nutrient content of the OM amendments applied to the soil or other growing media (Naguib et al., 2012; Taie et al., 2008). Table 2.3 shows the effect of different types of vermicompost on plant growth and metabolite production. The antioxidant concentration in crops is also enhanced by the application of organic manure in spite of regular chemical fertilizers (Bimova & Pokluda, 2009). Bilalis et al. (2009) reported that nicotine

production in *Nicotiana tabaccum* is stimulated by the incorporation of organic manure and better irrigation practices. Incorporation of organic manure in soil elevates plant defense capacity against pathogens along with high production of metabolites (Bommesha et al., 2012).

TABLE 2.1 Different Structural Forms of Bio-active Compounds in Plants.

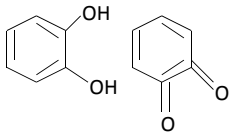
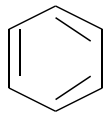
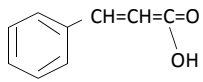
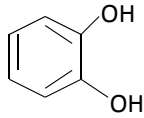
Sr. No.	Chemical characteristics		Functions
1	Presence of: -COOH, -OH, $-NH_2$ 		Structure stabilizing, anti-microbial, hypersensitivity providing
2	Availability of  Ring closed structures 	Short side chains	Photo-protective
	Long side chains -CH=CH=CH=CH-		
3	Availability of : $-NH_2$, -SH, -OH	-CH-CH=CH-CH-	
	Unsaturated carbon chains 		Antioxidant, antiradical

TABLE 2.2 Effect of Different Organic Fertilizers on Plant Metabolites.

Sr. No.	Organic fertilizers	Plant metabolites	Reference
1	Farm yard manure	Carotenoid and ascorbic acid content increased	Kipkosgei et al. (2003)
2	Green manure	High chlorophyll and fatty acid content	Mohammadi et al. (2011)
3	Vermicompost	Essential oil content increased	Singh et al. (2013)
4	Poultry manure	Increased protein, lipid, and carbohydrate concentration	Oyedeji et al. (2014)
5	Compost	High chlorophyll and leaf nutrient content	Belda et al. (2013)
6	Biochar	Increased content of tannins and organic acids	Schmidt et al. (2014)
7	Swine manure	High chlorophyll and leaf nutrient content	Kanto et al. (2012)
8	Compost tea	High sugar and phytonutrient concentration	Pant et al. (2012)
9	Tree bark extract	High pigment content in plants	Tanase et al. (2014)
10	Sea weed	High N assimilation and basal metabolism	Gonzalez et al. (2013)
11	Humic acid	Increased chlorophyll content	Zhang et al. (2014)
12	Pruning waste	Increased chlorophyll content	Morales-Corts et al. (2014)

TABLE 2.3 Effect of Vermicompost on Expression of Different Plant Metabolites.

Sr. No.	Type of vermicompost	Used plants	Metabolite	Reference
1	Cattle manure vermicompost	Pepper mint	Increased phenol, oil, chlorophyll, and carotenoid content	Ayyobi et al. (2013)
2	Commercial vermicompost	Bitter gourd	Increased phenol and flavonoid content	Benitez et al. (2013)
3	Pig manure vermicompost	Tomato and marigold	Enhanced chlorophyll content	Atiyeh et al. (2000)
4	Vermiwash	Chilly	High phytonutrients	Khan et al. (2014)
5	Vermicompost tea	Tomato	Enhanced nitrate reductase activity	Márquez-Quiroz et al. (2008)

Along with its beneficial effects, organic substances may also lead to the formation of some toxic compounds (Toussoun et al., 1967). For example, dihydroxystearic acid that is produced as a by-product during OM degradation in soil is highly toxic to higher plants. However, with the incorporation of various soil management practices like efficient drainage, tillage, application of lime and fertilizers, the problem of soil toxicity can be nullified to a considerable extent. The major influences of soil OM on the soil system can be studied under the following heads:

- Application of OM to soil renders the soil color black from brown,
- OM enhances soil physical conditions like granulation and water retention capacity coupled with the reduction of cohesion and plasticity,
- Betterment of soil cation exchange capacity is evident after applying OM to the soil system,
- The capacity of soil to supply and replenish the nutrient deficiency situations is increased by the incorporation of OM. OM not only acts as a source of nutrients for plants but also aids in the weathering of minerals through involvement of various organic acids.

Thus, OM can be regarded as a "store house" of nutrients for plants. Application of required OM coupled with the congenial environmental conditions may render better soil health and luxuriant plant growth.

2.6 FACTORS AFFECTING SOIL ORGANIC MATTER

Soil OM and soil N are affected by a series of important factors. Primarily, the soil OM is influenced by the type and quantity of plant or animal organic residues added to the soil system (Baldock, 2012). Some of the major factors which affect the soil OM are summarized as under:

- Climate
- Vegetation
- Soil physical properties
- Cropping and tillage
- Crop rotation, residues and plant nutrients
- Stubble burning or removal
- Overgrazing

2.6.1 INFLUENCE OF CLIMATE

Climate influences the dynamics of OM and its fractions in the soil system (Franzluebbers et al., 2001). Major climatic factors like temperature and precipitation play a prominent role on the levels of N and OM content in soil. If one moves from warmer to cooler regions, the amount of unmineralized OM and N will increase. This is because the warmer humid regions are more rich in microbes that lead to quick decomposition of the organic substrates leading to a lower C/N ratio than the cold regions where microbial activity is very low. In general, under comparable soil moisture levels the soil OM and N increase by 2–3 times by every 10°C decline in temperature (Buchan, 2014). In case of highly cultivated and well-drained soil, decomposition rate is high, accelerating the nutrient release but low residual C content. Like temperature, soil water content also holds huge influence on the OM and N accumulation capacity of soils. Clearly, with increasing soil moisture the amount of OM and N increase in soil. Thus, the synergistic effect of temperature and rainfall exert positive influence on the accumulation of OM and N in soil.

2.6.2 INFLUENCE OF VEGETATION

Natural vegetation overlying a soil type affects it positively with respect to its OM and N content. Vegetation types like grassland, forest, and so on, exert differential impact on the soil OM and N content (Pulido-Fernandez et al., 2013). Comparatively, soils under grasses accumulate more N and OM than forests. The sparse vegetation type in grasslands allows significantly lesser rate of decomposition of organic complexes promoting a high soil OM and N compared to the forest soil.

2.6.3 EFFECT OF SOIL PHYSICAL PROPERTIES

Soil physical properties like texture, drainage, aeration, and others, play a crucial role on the accumulation of OM and N in soil (Buschiazzo et al., 2004). Soil OM and N are comparatively high in fine-textured soil than coarse-textured soil. Thus, soil with more clay and silt percentage offer more OM accumulation potential than those with sand- and gravel-rich soil. The inherent interaction between clay and organomineral complexes

is high which safeguards the organic N in the form of clay-bound protein complex. This results in enhanced OM contents. Moreover, soils with good drainage and aeration are poor in OM content.

2.6.4 EFFECT OF CROPPING AND TILLAGE

Soils that undergo land-use change portray significant alteration in the level of OM and N (Curaqueo et al., 2010). Undisturbed natural soil is rich in OM than soil under cultivation. Virgin soil is high in OM and N because all the organic input from the overlying natural vegetation is straightly returned to the soil. On the other hand, soil under intensive agriculture, breaks the trend of OM and N accumulation due to high microbial activity and associated decomposition. Both conventional and modern tillage practices impart a variable effect on the soil OM content. The modern tillage practices lower the erosion risk and discourage the rapid decay of crop residues which maintains the OM budget of the soil for a longer time.

2.6.5 EFFECT OF CROP ROTATION, RESIDUES, AND PLANT NUTRIENTS

Sequence of cropping, incorporation of fertilizers, and other organic amendments influence the accumulation capacity of OM and N in soil (Campbell et al., 1991; Bierke et al., 2008). Soil that are well managed for years with the addition of appropriate amount of fertilizers, lime, and OM stay productive for long time and thus maintain a sound soil OM and N budget. On the other hand, the less productive or unproductive soils are poor in OM content. The extent of soil productivity depends highly on the amount of root and top soil residues that are returned to the soil after decay. Thus, the most productive arable soil will be low in OM compared to an undisturbed natural soil patch.

2.6.6 EFFECT OF STUBBLE BURNING OR REMOVAL

Stubble burning is a fire-setting pattern in agricultural fields after harvesting a crop. There are two main consequences of stubble burning in soil system. First, most of the plant carbon is lost in burning as CO_2. Second, the black

carbon formed after burning is added to the soil. Burning of crop residues leads to minimal increase in soil organic carbon content along with high earthworm population (Virto et al., 2007).

2.6.7 EFFECT OF OVERGRAZING

Overgrazing is a situation that arises when excessive amount of plant individuals are removed by primary consumers leading to desertification. Such incidences are of usual occurrence mainly in the semi-arid regions where vegetation is very sparse. Overgrazing directly influences the microbial communities in soil, thus hampering important soil processes like decomposition, mineralization, and others (Abril & Bucher, 1999). Thus, OM accumulation is affected by overgrazing. Overgrazing also leads to soil compaction, low water retention capacity, aeration, and so on.

KEYWORDS

- **soil organic matter**
- **disintegration**
- **climate**
- **natural vegetation**
- **overgrazing**

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